

WHAT IS CLAIMED AS NEW AND DESIRED TO BE SECURED BY LETTERS
PATENT OF THE UNITED STATES IS:

1. An arrayed waveguide grating optical multiplexer/demultiplexer comprising:
at least one first optical waveguide;
a first slab waveguide;
an arrayed waveguide connected to said at least one first optical waveguide via said
first slab waveguide;
a second slab waveguide; and
a plurality of second optical waveguides connected to said arrayed waveguide via
said second slab waveguide, a number (N_{ch}) of the plurality of second optical waveguides
being determined to substantially satisfy the following equation:

$$\Delta f_{fsr} = \Delta f_{ch} \cdot N_{ch}$$

where Δf_{fsr} : Free Spectral Range of the arrayed waveguide grating optical
multiplexer/demultiplexer

Δf_{ch} : a frequency interval between frequencies of lights to be input to the
arrayed waveguide grating optical multiplexer/demultiplexer for being
multiplexed or lights to be output from the arrayed waveguide grating optical
multiplexer/demultiplexer after being demultiplexed.

2. An arrayed waveguide grating optical multiplexer/ demultiplexer according to
Claim 1, further comprising:
at least one multi-mode waveguide having a first end portion and a second end
portion, a second width of the second end portion being larger than a first width of the first
end portion, the first end portion of each of said at least one multi-mode waveguide being
connected to each of said at least one first optical waveguide, the second end portion of each

of said at least one multi-mode waveguide being connected to said first slab waveguide, a width of said at least one multi-mode waveguide increasing from the first end portion toward the second end portion and being configured to realize multi-mode.

3. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 2, further comprising:

at least one straight waveguide each provided between each of said at least one first optical waveguide and each of said at least one multi-mode waveguide, said at least one straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

4. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 2, further comprising:

at least one constant width waveguide provided between each of said at least one first optical waveguide and each of said at least one multi-mode waveguide, said at least one constant width waveguide having a substantially constant width which is substantially equal to the first width of the first end portion of said at least one multi-mode waveguide.

5. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 4, further comprising:

at least one straight waveguide provided between each of said at least one first optical waveguide and each of said at least one constant width waveguide, said at least one straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

6. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 2, wherein said at least one multi-mode waveguide has a trapezoidal shape in which the first end portion is an upper base and the second end portion is a lower base.

7. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 2, wherein said at least one first optical waveguide comprises a plurality of first optical waveguides and said at least one multi-mode waveguides comprises a plurality of multi-mode waveguides, and wherein all of said plurality of first optical waveguides are connected to all of said plurality of multi-mode waveguides, respectively.

8. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 2, wherein said at least one first optical waveguide comprises a plurality of first optical waveguides at least one of which is connected to said first slab waveguide without interposing said at least one multi-mode waveguide.

9. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 1, further comprising:

a plurality of multi-mode waveguides each having a third end portion and a fourth end portion, a fourth width of the fourth end portion being larger than a third width of the third end portion, the third end portion of each of said plurality of multi-mode waveguides being connected to each of said plurality of second optical waveguides, the fourth end portion of each of said plurality of multi-mode waveguides being connected to said second slab waveguide, a width of said multi-mode waveguides increasing from the third end portion toward the fourth end portion and being configured to realize multi-mode.

10. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 9, further comprising:

a plurality of straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of multi-mode waveguides, each of the said plurality of straight waveguides having a width narrower than the second optical waveguide width of each of said plurality of second optical waveguides.

11. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 9, further comprising:

a plurality of constant width waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of multi-mode waveguides, each of said plurality of constant width waveguides having a substantially constant width which is substantially equal to the third width of the third end portion.

12. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 11, further comprising:

a plurality of straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of constant width waveguides, each of said plurality of straight waveguides having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

13. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 9, wherein each of said plurality of multi-mode waveguides has a trapezoidal shape in which the third end portion is an upper base and the fourth end portion is a lower base.

14. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 1, further comprising:

at least one first multi-mode waveguide having a first end portion and a second end portion, a second width of the second end portion being larger than a first width of the first end portion, the first end portion of each of said at least one first multi-mode waveguide being connected to each of said at least one first optical waveguide, the second end portion of each of said at least one first multi-mode waveguide being connected to said first slab waveguide, a width of said at least one first multi-mode waveguide increasing from the first end portion toward the second end portion and being configured to realize multi-mode; and

a plurality of second multi-mode waveguides each having a third end portion and a fourth end portion, a fourth width of the fourth end portion being larger than a third width of the third end portion, the third end portion of each of said plurality of second multi-mode waveguides being connected to each of said plurality of second optical waveguides, the fourth end portion of each of said plurality of second multi-mode waveguides being connected to said second slab waveguide, a width of said second multi-mode waveguides increasing from the third end portion toward the fourth end portion and being configured to realize multi-mode.

15. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 14, further comprising:

at least one first straight waveguide each provided between each of said at least one first optical waveguide and each of said at least one first multi-mode waveguide, the at least one first straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

16. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 15, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second multi-mode waveguides, the second straight waveguides each having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

17. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 14, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second multi-mode waveguides,

the second straight waveguides each having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

18. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 14, further comprising:

at least one first constant width waveguide each provided between each of said at least one first optical waveguide and each of said at least one first multi-mode waveguide, the first constant width waveguide having a substantially constant width which is substantially equal to the first width of the first end portion of said at least one first multi-mode waveguide.

19. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 18, further comprising:

at least one first straight waveguide each provided between each of said at least one first optical waveguide and each of said first constant width waveguide, the first straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

20. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 18, further comprising:

a plurality of second constant width waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of multi-mode waveguides, each of the second constant width waveguides having a substantially constant width which is substantially equal to the third width of the third end portion.

21. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 20, further comprising:

at least one first straight waveguide each provided between each of said at least one

first optical waveguide and each of said at least one first constant width waveguide, the at least one first straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

22. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 21, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second constant width waveguide, each of the second straight waveguides having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

23. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 14, further comprising:

a plurality of second constant width waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second multi-mode waveguides, the second constant width waveguides each having a substantially constant width which is substantially equal to the third width of the third end portion.

24. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 23, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second constant width waveguides, the second straight waveguides each having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

25. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 24, further comprising:

at least one first constant width waveguide each provided between said at least one

first optical waveguide and said at least one first multi-mode waveguide, the at least one first constant width waveguide having a substantially constant width which is substantially equal to the first width of the first end portion of said at least one first multi-mode waveguide.

26. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 14, wherein said at least one first multi-mode waveguide has a trapezoidal shape in which the first end portion is an upper base and the second end portion is a lower base, and wherein each of said plurality of second multi-mode waveguides has a trapezoidal shape in which the third end portion is an upper base and the fourth end portion is a lower base.

27. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 1, further comprising:

at least one single-mode waveguide having a first end portion and a second end portion, a second width of the second end portion being larger than a first width of the first end portion, the first end portion of each of said at least one single-mode waveguide being connected to each of said at least one first optical waveguide, the second end portion of each of said at least one single-mode waveguide being connected to said first slab waveguide, a width of said at least one single-mode waveguide increasing from the first end portion toward the second end portion and being configured to realize single-mode.

28. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 27, further comprising:

at least one straight waveguide each provided between each of said at least one first optical waveguide and each of said at least one single-mode waveguide, said at least one straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

29. An arrayed waveguide grating optical multiplexer/ demultiplexer according to

Claim 27, further comprising:

at least one constant width waveguide provided between each of said at least one first optical waveguide and each of said at least one single-mode waveguide, said at least one constant width waveguide having a substantially constant width which is substantially equal to the first width of the first end portion of said at least one single-mode waveguide.

30. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 29, further comprising:

at least one straight waveguide provided between each of said at least one first optical waveguide and each of said at least one constant width waveguide, said at least one straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

31. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 27, wherein said at least one single-mode waveguide has a trapezoidal shape in which the first end portion is an upper base and the second end portion is a lower base.

32. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 27, wherein said at least one first optical waveguide comprises a plurality of first optical waveguides and said at least one single-mode waveguides comprises a plurality of single-mode waveguides, and wherein all of said plurality of first optical waveguides are connected to all of said plurality of single-mode waveguides, respectively.

33. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 27, wherein said at least one first optical waveguide comprises a plurality of first optical waveguides at least one of which is connected to said first slab waveguide without interposing said at least one single-mode waveguide.

34. An arrayed waveguide grating optical multiplexer/ demultiplexer according to

Claim 1, further comprising:

a plurality of single-mode waveguides each having a third end portion and a fourth end portion, a fourth width of the fourth end portion being larger than a third width of the third end portion, the third end portion of each of said plurality of single-mode waveguides being connected to each of said plurality of second optical waveguides, the fourth end portion of each of said plurality of single-mode waveguides being connected to said second slab waveguide, a width of said single-mode waveguides increasing from the third end portion toward the fourth end portion and being configured to realize single-mode.

35. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 34, further comprising:

a plurality of straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of single-mode waveguides, each of the said plurality of straight waveguides having a width narrower than the second optical waveguide width of each of said plurality of second optical waveguides.

36. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 34, further comprising:

a plurality of constant width waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of single-mode waveguides, each of said plurality of constant width waveguides having a substantially constant width which is substantially equal to the third width of the third end portion.

37. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 36, further comprising:

a plurality of straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of constant width waveguides, each of

said plurality of straight waveguides having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

38. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 34, wherein each of said plurality of single-mode waveguides has a trapezoidal shape in which the third end portion is an upper base and the fourth end portion is a lower base.

39. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 1, further comprising:

at least one first single-mode waveguide having a first end portion and a second end portion, a second width of the second end portion being larger than a first width of the first end portion, the first end portion of each of said at least one first single-mode waveguide being connected to each of said at least one first optical waveguide, the second end portion of each of said at least one first single-mode waveguide being connected to said first slab waveguide, a width of said at least one first single-mode waveguide increasing from the first end portion toward the second end portion and being configured to realize single-mode; and

a plurality of second single-mode waveguides each having a third end portion and a fourth end portion, a fourth width of the fourth end portion being larger than a third width of the third end portion, the third end portion of each of said plurality of second single-mode waveguides being connected to each of said plurality of second optical waveguides, the fourth end portion of each of said plurality of second single-mode waveguides being connected to said second slab waveguide, a width of said second single-mode waveguides increasing from the third end portion toward the fourth end portion and being configured to realize single-mode.

40. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 39, further comprising:

at least one first straight waveguide each provided between each of said at least one first optical waveguide and each of said at least one first single-mode waveguide, the at least one first straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

41. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 40, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second single-mode waveguides, the second straight waveguides each having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

42. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 39, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second single-mode waveguides, the second straight waveguides each having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

43. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 39, further comprising:

at least one first constant width waveguide each provided between each of said at least one first optical waveguide and each of said at least one first single-mode waveguide, the first constant width waveguide having a substantially constant width which is substantially equal to the first width of the first end portion of said at least one first single-mode waveguide.

44. An arrayed waveguide grating optical multiplexer/ demultiplexer according to

Claim 43, further comprising:

at least one first straight waveguide each provided between each of said at least one first optical waveguide and each of said first constant width waveguide, the first straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

45. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 43, further comprising:

a plurality of second constant width waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of single-mode waveguides, each of the second constant width waveguides having a substantially constant width which is substantially equal to the third width of the third end portion.

46. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 45, further comprising:

at least one first straight waveguide each provided between each of said at least one first optical waveguide and each of said at least one first constant width waveguide, the at least one first straight waveguide having a width narrower than a first optical waveguide width of said at least one first optical waveguide.

47. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 46, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second constant width waveguide, each of the second straight waveguides having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

48. An arrayed waveguide grating optical multiplexer/ demultiplexer according to

Claim 39, further comprising:

a plurality of second constant width waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second single-mode waveguides, the second constant width waveguides each having a substantially constant width which is substantially equal to the third width of the third end portion.

49. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 48, further comprising:

a plurality of second straight waveguides each provided between each of said plurality of second optical waveguides and each of said plurality of second constant width waveguides, the second straight waveguides each having a width narrower than a second optical waveguide width of each of said plurality of second optical waveguides.

50. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 49, further comprising:

at least one first constant width waveguide each provided between said at least one first optical waveguide and said at least one first single-mode waveguide, the at least one first constant width waveguide having a substantially constant width which is substantially equal to the first width of the first end portion of said at least one first single-mode waveguide.

51. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 39, wherein said at least one first single-mode waveguide has a trapezoidal shape in which the first end portion is an upper base and the second end portion is a lower base, and wherein each of said plurality of second single-mode waveguides has a trapezoidal shape in which the third end portion is an upper base and the fourth end portion is a lower base.

52. An arrayed waveguide grating optical multiplexer/ demultiplexer according to Claim 2, wherein said at least one first optical waveguide comprises a plurality of first optical

waveguides, said at least one multi-mode width waveguide comprises a plurality of multi-mode width waveguides, and wherein at least one of the plurality of first optical waveguides is connected to said first slab waveguide via at least one of the plurality of multi-mode waveguides.

53. An arrayed waveguide grating optical multiplexer/demultiplexer according to Claim 1, wherein the number (N_{ch}) of the plurality of second optical waveguides is an odd number.

54. An arrayed waveguide grating optical multiplexer/demultiplexer according to Claim 1, wherein the number (N_{ch}) of the plurality of second optical waveguides is at least three.

55. An arrayed waveguide grating optical multiplexer/demultiplexer comprising:
at least one first optical waveguide;
a first slab waveguide;
an arrayed waveguide connected to said at least one first optical waveguide via said first slab waveguide;

a second slab waveguide; and

a plurality of second optical waveguides connected to said arrayed waveguide via said second slab waveguide, a number (N_{ch}) of the plurality of second optical waveguides being determined, based on a frequency interval (Δf_{ch}) between frequencies of lights to be input to the arrayed waveguide grating optical multiplexer/demultiplexer for being multiplexed or lights to be output from the arrayed waveguide grating optical multiplexer/demultiplexer after being demultiplexed, such that the arrayed waveguide grating optical multiplexer/demultiplexer functions as an interleaver optical wavelength multiplexer/demultiplexer.

56. An arrayed waveguide grating optical multiplexer/demultiplexer according to Claim 55, wherein the number (N_{ch}) of the plurality of second optical waveguides is an odd number.

57. An arrayed waveguide grating optical multiplexer/demultiplexer according to Claim 55, wherein the number (N_{ch}) of the plurality of second optical waveguides is at least three.

58. A method for manufacturing an arrayed waveguide grating optical multiplexer/demultiplexer, comprising:

providing at least one first optical waveguide;

providing a first slab waveguide;

providing an arrayed waveguide connected to said at least one first optical waveguide via said first slab waveguide;

providing a second slab waveguide;

providing a plurality of second optical waveguides connected to said arrayed waveguide via said second slab waveguide; and

determining a number (N_{ch}) of the plurality of second optical waveguides to substantially satisfy the following equation:

$$\Delta f_{fsr} = \Delta f_{ch} \cdot N_{ch}$$

where Δf_{fsr} : Free Spectral Range of the arrayed waveguide grating optical multiplexer/demultiplexer

Δf_{ch} : a frequency interval between frequencies of lights to be input to the arrayed waveguide grating optical multiplexer/demultiplexer for being multiplexed or lights to be output from the arrayed waveguide grating optical multiplexer/demultiplexer after being demultiplexed.

59. A method for manufacturing an arrayed waveguide grating optical multiplexer/demultiplexer, comprising:

- providing at least one first optical waveguide;
- providing a first slab waveguide;
- providing an arrayed waveguide connected to said at least one first optical waveguide via said first slab waveguide;
- providing a second slab waveguide;
- providing a plurality of second optical waveguides connected to said arrayed waveguide via said second slab waveguide; and
- determining a number (N_{ch}) of the plurality of second optical waveguides, based on a frequency interval (Δf_{ch}) between frequencies of lights to be input to the arrayed waveguide grating optical multiplexer/demultiplexer for being multiplexed or lights to be output from the arrayed waveguide grating optical multiplexer/demultiplexer after being demultiplexed, such that the arrayed waveguide grating optical multiplexer/demultiplexer functions as an interleaver optical wavelength multiplexer/demultiplexer.

60. An optical multiplexer/demultiplexer system comprising:

an arrayed waveguide grating optical multiplexer/demultiplexer comprising:

- at least one first optical waveguide;
- a first slab waveguide;
- an arrayed waveguide connected to said at least one first optical waveguide via said first slab waveguide;
- a second slab waveguide; and
- a plurality of second optical waveguides connected to said arrayed waveguide via said second slab waveguide, a number (N_{ch}) of the plurality of second

optical waveguides being determined to substantially satisfy the following equation:

$$\Delta f_{\text{fsr}} = \Delta f_{\text{ch}} \cdot N_{\text{ch}}$$

where Δf_{fsr} : Free Spectral Range of the arrayed waveguide grating optical multiplexer/demultiplexer

Δf_{ch} : a frequency interval between frequencies of lights to be input to the arrayed waveguide grating optical multiplexer/demultiplexer for being multiplexed or lights to be output from the arrayed waveguide grating optical multiplexer/demultiplexer after being demultiplexed;
and

at least two optical multiplexer/demultiplexer units each connected to each of the plurality of second optical waveguides.